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MICROSCOPIC EXTRATERRESTRIAL PARTICLES FROM

THE ANTARCTIC PENINSULA

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ABSTRACT

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Microscopic extraterrestrial particles were recovered from meltwater of snow core samples collected as a part of American oversnow traverse operations in the region at the base of the Antarctic Peninsula on the Antarctic ice cap during the austral summer of 1961-1962. While several types of particles were recognized, black, metallic spherules and yellowish, glassy spherules were most common. The metallic spherules ranged from 10 to 170 microns in diameter, had physical properties generally similar to magnetite, and were rich in iron. The surfaces of many metallic spherules were textured, partly reflecting the internal arrangement of mineralogical components, and partly the products of apparent impact with smaller particles. The glassy spherules ranged from 10 to 300 microns in diameter, had physical properties similar to various forms of silica glass, and were rich in silica. A few glassy spherules appeared to be akin to tektites.

Both metallic and glassy spherules were found at each station sampled, although in varying amounts which could not be correlated with annual snow layers. This was caused in part by the influence of snow accumulation and local and regional topography upon spherule occurrence. Direct relations of

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frequency of spherule occurrence and annual snow deposit were suggested by the data, while an inverse relation between snow accumulation and mean spherule size was discovered. Exceptions to these relations were attributable to local and regional topographical and meteorological effects.

The cumulative rate of deposition of metallic spherules was found to be essentially uniform for the area of the Antarctic Peninsula Traverse, although at individual stations the rates were divergent because of local factors. The annual mass accretion of metallic particles over the earth's surface was estimated from these results at about 1×10^5 metric tons. This accretion rate was less than that found for stations at higher geomagnetic latitudes, suggesting a possible magnetic influence upon particle deposition.

AUTHOR

INTRODUCTION

It has been known for many years that particulate matter occurs in the snows of polar regions. As early as 1870, Nordenskiöld discovered nickel-iron dust on the Greenland ice cap. He referred to this material as Cryoconite (ice dust), and suggested that the metallic particles might be of extraterrestrial origin. More recently, studies of similar materials from polar snows were undertaken as suggested by Nininger (1952) to eliminate obvious sources of terrestrial and industrial contamination of dust samples. During the International Geophysical Year, the first collections of particulates from Antarctic snows were made by Nishibori and Ishizaki (1959), followed by those of Thiel and Schmidt (1961) and Mrkos (1962).

This paper describes the results of a study of particulates collected from snows of a regional area of the Antarctic ice cap. Particles were recovered

from the meltwater of snow core samples 7.6 cm in diameter and 10 m in length which were taken at 11 stations along the route of the Antarctic Peninsula Traverse during the austral summer of 1961-1962. The locations of sample sites are shown in figure 1. Entire snow cores were shipped, in special containers which were kept under refrigeration at all times, to our laboratory at the Geophysical and Polar Research Center. This was done to prevent fragmentation of fragile, glassy particles discovered earlier (Thiel and Schmidt, 1961). While a few snow core sections apparently suffered minor recrystallization during shipment, this did not affect their value for particulate study. Considering the great distances over which they were transported, all snow samples arrived in remarkably good condition.

To guard against contamination of the samples by ordinary room dust or by airborne particles of industrial origin, the entire processing operation was carried out in a dust-free enclosure designed and constructed especially for this project (Schmidt, 1963). While held under cold storage, the snow core samples were examined and described. They were then cut into sections approximately 25 cm long. Each section was separately melted and filtered in one continuous operation, employing an adapted Millipore filter apparatus. With the measured snow accumulation for stations of the Antarctic Peninsula Traverse, each core section represented from one-third to one-fifth of a year. This short span of time provided good control for estimation of the annual accretion of particles to the earth.

RESULTS

The residues obtained by filtering meltwater from each core section were examined under oblique illumination at 100X magnification using a Bausch and

Lomb zoom-type binocular microscope. A mechanical stage was used to manipulate the residues for scanning. At this time, particles were individually identified, measured, described, photographed, and separated for subsequent chemical and physical analyses. Primary attention was devoted to spherical particles, because this form is rarely produced by ordinary terrestrial geological processes.

A total of 1,090 particles, representing six of the eight major particle classes (Schmidt, 1963a), was recognized (Table I). Most abundant were black, metallic spherules (65 percent) and yellow, glassy spherules (29 percent). These proportions agree well with Buddhue's (1950) data for similar material. Descriptions of these particles are given below.

Metallic Spherules

Nearly all metallic particles recovered in this work were perfect spheres which ranged from 10μ to 170μ in diameter. While a few oval, spindle-shaped, and mammillary metallic particles were encountered, these were very rare. Color of the metallic spherules varied from jet black to dark gray, although part of this variation was produced by variations in surface texture. The largest surface features (up to 10μ on 60μ spherules) were shallow, elliptical depressions similar in appearance to the "cupules" described by Murray (1883). Cupules resemble the effect produced by gently pressing one's thumb onto a ball of soft clay. Some examples are shown at low magnification in Plate 1. Fine details of surface texture were also present. These showed subtle variations which were the basis for recognition of three types of metallic spherules (Schmidt, et al., 1963): Type I, smooth, polished, black, metallic spherules with no apparent surface detail; Type II, spherules with lower luster, and an irregular, corrugated surface comprised of two patterns of linear "ridges" and "furrows" (about 0.5μ wide) which intersected at approximately right angles; Type III, spherules of

low luster, with a myriad of minute (0.5μ in diameter), randomly distributed, shallow, roughly circular, unconnected depressions or "pits." Spherules which exhibited fine surface textures (Types II and III) were about three times more abundant than those which did not (Type I).

In addition to their metallic luster, metallic spherules were found to be moderately to strongly magnetic, being readily attracted to the tip of a magnetized needle. The hardness of the spherules was crudely estimated to be about 5 on the moh scale; they could be broken, but only by exerting active pressure through the needle. When broken, the metallic spherules presented a dull-gray to gray-black, irregular to hackly fracture surface. Spherules tested in this way by the writer differed from those described by Langway (1963) in that they were not hollow.

In polished surface under reflected polarized light, the metallic spherules were found to be composed of several mineral species (Table II). The bulk of each spherule examined was comprised of a light-pinkish-gray, isotropic mineral of moderate to low reflectivity, which was identified as magnetite. This was confirmed through X-ray powder photographs of individual spherules. Also present as thin lamellae, tiny blebs, and minute grains was a pale, cream-colored mineral of higher reflectivity than magnetite; this minor phase was tentatively identified as schreibersite, but identification has not yet been confirmed by X-ray work. A third, purple-colored mineral of lower reflectivity than magnetite was also present as scattered, irregular blebs; this mineral has not yet been identified. The lamellae of mineral phases were found to intersect in a pattern similar to that shown on the surface of Type II spherules.

Density measurements were made by observing the rate of spherule fall through a tube containing 1-methoxynaphthelene and applying Stokes' Law. Calibration tests using drops of mercury of the same size as spherules showed this

procedure to yield results which differed from the accepted value for the density of mercury by less than 10 percent. The mean density of metallic spherules was 5.1 gm cm^{-3} (Table II), consistent with that for magnetite.

Electron probe analyses of a representative group of metallic spherules showed them to contain about 70 percent iron, with traces of titanium, manganese, and silica (Table III); this composition is compatible with that reported for magnetite. Nickel was not detected in these spherules; it was either present in small amounts which could not be detected, or was absent in these samples. Analyses of metallic spherules from the Antarctic Peninsula Traverse are thus essentially identical to the "iron-rich spherules without nickel" of Wright, et al., (1963).

Glassy Spherules

Most glassy particles examined were perfect spheres which ranged from 20μ to 300μ in diameter. Rarely, an oval or hemispherical particle was found. The most distinguishing characteristic of glassy spherules was their translucence. Resembling a child's marble, they transmitted oblique-incident light and focussed it to a brilliant spot on the opposite side (Plate 2). Colors of glassy spherules varied considerably; clear, yellow, tan, brown, green-gray, and smoky-black particles were observed, although yellow and clear particles were most common. Most glassy spherules had a vitreous luster, which was accentuated because of their smooth, polished surface. A few glassy spherules gave faint suggestions of detailed surface texture, consisting of minute pits similar to those shown by metallic spherules, the glassy spherules were non-magnetic, although a few contained opaque inclusions. Some glassy spherules appeared to be broken, and these revealed a smooth, conchoidal fracture. Rarely, hollow glassy spheres were found, as shown in Plate 2, no. 4.

In transmitted, polarized light, most glassy spherules gave no hint of crystallographic features and were isotropic in optical character (Table IV). Shades of yellow were the most common colors. A few glassy spherules (such as spherule 9, Table IV) were olive brown in color, showed mottled internal structure, and had marked anisotropism with wavy extinction. Refractive indices ranged from about 1.48 to about 1.52, but most were within the narrow range from 1.50 to 1.52. These values were reproducible within 0.01, with comparable precision in measurement because of the small size of the spherules.

Only a few density values were obtained because of great difficulty in observing the fall of glassy spherules; these average slightly greater than 2 gm cm^{-3} .

Electron probe analyses of two glassy spherules indicate that they are very rich in silica (Table III). Additional analyses are in progress. These preliminary data suggest that the glassy spherules recovered from the area of the Antarctic Peninsula Traverse are most similar to naturally fused quartz. It is possible, but far from proved, that the glassy spherules may be akin to tektites.

Occurrence

Particulate samples from the Antarctic Peninsula Traverse are unique in that they represent a regional area of the earth's surface. Data for metallic spherules (the most abundant class of particle recovered from each station) were compared in an attempt to provide insight into particle occurrence throughout the area (Table V).

Glaciological measurements (Shimizu, personal communication, 1962) and seismic determinations (Behrendt, personal communication, 1963) show that snow accumulation varied among the stations occupied by the traverse. Figure 2 shows

that snow accumulation was greatest in the northern part of the traverse area near the Robert English Coast, while smaller accumulation was present in the lee of a marked surface ridge. Three lines of evidence suggested that spherule occurrence was apparently related to this regional pattern of snow accumulation. First, an approximate, inverse relation of mean spherule size to snow accumulation was indicated (fig. 3). Although considerable scatter was present, this graph represents the fact that greater proportions of smaller particles were found at stations where snow accumulation was greatest. Second, the frequency of spherule occurrence showed an apparent, direct relation to snow accumulation (fig. 4). Again, the data show scatter, but it can be seen that metallic spherules had highest frequency where snow accumulation was greatest. Finally, estimates of the annual deposit of metallic spherules were prepared from data of each station, assuming that the spherules fell to earth during deposition of the snow layer in which they were found and that they had been deposited uniformly over the entire planet. Figure 5 shows an apparent direct relation of annual deposit of metallic spherules and snow accumulation for 7 of the 11 stations sampled (Stations 224, 320, 700, 764, 840, 940, and 1008). These stations were widely separated (fig. 1), had markedly different elevations, and showed greatly differing surface wind directions (Table V). Yet, for these stations, where snow accumulation was less, annual deposit of metallic spherules was less, and conversely. Exceptions to this relationship were shown by Stations 464, 496, 572, and 636. While these stations had lower snow accumulation, they indicated relatively high annual spherule deposits. However, these stations had many characteristics in common. Each was established in the vicinity of local nunataks, which probably locally altered the general pattern of snow accumulation. Furthermore, Stations 464, 496, and 572 were located in the immediate shadow of the regional surface ridge (figs. 2 and 5). Although Station 636 was on the windward side of this ridge, it was situated on a broad, flat bench bordered by steep slopes. Finally,

these were the only stations in the area where north-easterly surface wind directions were found. Together, these three relationships suggest to the writer that meteorological factors were intimately intertwined with the occurrence of metallic spherules in this area.

Data for the occurrence of glassy spherules showed considerably more scatter because fewer were identified, but suggested similar relationships. Studies in progress at present will examine the occurrence of glassy spherules in greater detail.

Unfortunately, no obvious correlation of particle occurrence in yearly snow layers was demonstrated among the several stations. This melancholy result can be attributed, in part, to the large spacings of stations (about 100 km apart). In addition, however, extensive wind-produced modifications in snow surface (Behrendt; Shimizu; personal communications, 1963) probably were significant in preventing correlations. In light of these results, the writer finds it difficult to place confidence in Marshall's (1959, 1963) suggestion that particulate matter can be used as a quantitative stratigraphic parameter for correlation of glaciological measurements over broad areas of a polar ice cap.

DISCUSSION

The writer regards the particles recovered in this work as extraterrestrial in origin. While many previous workers have argued that metallic spherules must contain nickel if an extraterrestrial origin is to be considered likely (for example, Fredriksson, 1961), it is difficult to reasonably postulate possible sites of terrestrial or industrial origin for the present samples in view of their physical characteristics and the nature of their occurrence. No rocks in the traverse area were found which exhibited mineral species similar to these particles (Laudon, et al., 1963). Furthermore, it seems unlikely that particles

of the composition reported here could be produced by volcanic action. Even if this were possible, the nearest known active volcano which could have supplied particles to these recent snow samples is Mt. Erebus, located in McMurdo Sound, about 2,500 km from the traverse area. Glasstone's (1962) fallout equations suggest that it would be impossible for particles of the size collected to be transported such distances. Transportation to the traverse area would be even more difficult for particles of industrial origin, because of the remoteness of the area and paucity of manufacturing centers. In addition, the area of the Antarctic Peninsula Traverse is far removed from ocean shipping lanes, making it improbable that the particles could be soot from vessels which rarely come near. Finally, tentative results from a current study of deep snow samples from the South Pole indicate that particles similar in every respect to those described here occur in snow layers deposited as long ago as about 1500 A.D.; this work will be the subject of a later paper.

The magnetite composition of metallic spherules recovered from the snows of the Antarctic Peninsula region is consistent with the presence of small, iron-oxide (magnetite) dust grains in space, postulated by Wood (1963) in his hypothesis for the origin of chondritic meteorites. Perhaps particles collected by the earth in modern times may represent a continuation of that primeval process.

It would appear that fewer metallic spherules occur in snows of the Antarctic Peninsula than in those of northern Greenland (Langway, 1963). The average number of spherules per liter of snow meltwater for Antarctic Peninsula samples was about 20 times less than that found for Greenland. In addition, estimated annual accretion rates differed greatly, from 1.2×10^5 metric tons (mean Antarctic Peninsula) to 9.1×10^5 metric tons (Greenland). At the present stage of spherule studies, this discrepancy should not be considered discouraging.

Little is known about the areal character of spherule occurrence, and the off-made assumption that the particles were uniformly deposited upon the earth may require review. The apparent disagreement in these results may be the first clue to such an important discovery. A natural cause for variations in spherule deposition rates among sampling stations may be related to the earth's magnetic field, as suggested by Hunter and Parkin (1962); note that the Greenland site was at a much higher geomagnetic latitude than the Antarctic Peninsula region. The earth's magnetic field may thus cause a primary variation in spherule deposit, with local meteorological and topographical factors producing a secondary control on particle occurrence.

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TABLE I.- OCCURRENCE OF PRINCIPAL PARTICLE TYPES, ANTARCTIC PENINSULA TRAVERSE,
1961-1962 (AFTER SCHMIDT, 1963)

Particle type	Amount	Percent	Buddhue percent
Black, metallic spherules	715	65	69
Mammillated, metallic spherules	17	2	
Glassy spherules	319	29	29
Irregular, angular fragments	6	1	
Scoriaceous or cindery particles	25	2	
Fibrous particles	n.o.*		
Coated particles	8	1	
Fluffy particles	<u>n.o.*</u>		
TOTAL:	1090		

*n.o. = not observed

TABLE II
Physical Properties of Metallic Spherules, Antarctic Peninsula Traverse

Spherule	Size (microns)	Color (shades of light gray)	Reflectivity	Surface	Optical Character	Internal Reflections	Rotation Properties	Apparent Crystallographic Features	Magnetism	Density
1	60	brownish- pink	moderate to low	ridged and furrowed	isotropic	none	n.o.*	intersecting lamellae	moderate	lost
2	40	brownish- pink	moderate to low	ridged, w/ pits	isotropic	none	n.o.	lamellae	moderate	4.7
3	30	pinkish	moderate	ridged, w/ pits	isotropic	none	n.o.	lamellae	moderate	lost
4	40	pinkish	moderate	ridged and furrowed	isotropic	none	n.o.	intersecting lamellae	moderate to strong	lost
5	50	brownish- pink	moderate to low	pitted	isotropic	none	n.o.	none	moderate	5.3
6	40	pinkish	moderate	pitted	isotropic	none	n.o.	none	moderate	4.8
7	40	pinkish- brown	moderate to low	pitted	isotropic	none	n.o.	none	moderate	5.1
8	60	purplish	moderate to high	smooth	isotropic	none	n.o.	none	strong	4.7
9	50	pinkish	moderate	pitted	isotropic	none	n.o.	none	moderate	lost
10	40	pinkish- purple	low	pitted	isotropic	none	n.o.	none	moderate	5.0
11	40	pinkish	moderate to high	ridged and furrowed	isotropic	none	n.o.	intersecting lamellae	moderate	lost
12	30	pinkish	moderate	ridged and furrowed	isotropic	none	n.o.	intersecting lamellae	moderate	7.1
13	100	pinkish- cream	moderate	pitted	isotropic	none	n.o.	none	moderate to strong	4.9
14	60	pinkish	moderate to high	ridged, w/ pits	isotropic	none	n.o.	lamellae	moderate	4.7
15	40	purplish	moderate	smooth	isotropic	none	n.o.	none	moderate to strong	lost
16	50	pinkish	moderate to low	ridged, w/ pits	isotropic	none	n.o.	lamellae	moderate	lost
17	30	pinkish	moderate	ridged, w/ pits	isotropic	none	n.o.	----	moderate	5.0
18	40	pinkish	moderate to high	smooth, w/ pits	isotropic	none	n.o.	none	moderate	lost
19	40	pinkish	moderate to low	ridged, w/ pits	isotropic	none	n.o.	----	moderate	lost
20	40	pinkish	moderate	ridged, w/ pits	isotropic	none	n.o.	----	moderate	5.2
5.1 = MEAN										

COMPARISON

Iron	white	high	----	isotropic	none	----	granular texture	high	7.85
Magnetite	brownish- pink	low	----	isotropic	none	----	----	high	5.18
Chromite	brownish	low	----	isotropic	brown	----	granular	moderate	4.6
Ilmenite	cream	low	----	anisotropic	brown	----	----	moderate	4.7

*NOTE: n.o. = not observable

TABLE III
Physical Properties of Glassy Spherules, Antarctic Peninsula Traverse

Spherule	Size (microns)	Color	Pleochroism	Surface	Crystallographic Features	Inclusions	Optical Character	Birefringence	Refractive Index	Density (gm cm ⁻³)
1	60	yellow to clear	none	smooth, w/ conchoidal fracture	none	opaque liquid (?)	isotropic	none	1.48 < n < 1.52	lost
2	70	yellow	none	smooth	none	opaque	isotropic	none	1.48 < n < 1.52	lost
3	100	yellow-orange	none	smooth	none	none	isotropic	none	1.52	2.3
4	50	clear yellow	none	smooth	none	none	isotropic	none	1.50	lost
5	40	clear	none	pitted	none	opaque	isotropic	none	1.50 < n < 1.52	lost
6	80	yellow	none	smooth	none	none	isotropic	none	1.50 < n < 1.52	2.5
7	120	clear	none	smooth, w/ conchoidal fracture	none	opaque	pseudo isotropic	yellow rim (strain feature?)	1.50	2.4
8	60	yellow	none	smooth	none	none	isotropic	none	1.50 < n < 1.52	lost
9	50	olive brown	faint	irregular	mottled internal structure	none	anisotropic, wavy extinction	cream-yellow-tan	1.50 < n < 1.52	lost
10	70	clear	none	smooth	none	none	isotropic	none	1.50	1.9
11	50	clear	none	smooth	none	none	isotropic	none	1.50 < n < 1.52	lost
2.3 = MEAN										
<u>Comparison</u>										
Lechatelierite		clear	none	irregular curves	none	bubbles	isotropic	none	1.458	2.19 (Winchell and Winchell, 1951)
Leucite		colorless, white, gray	none	----	pseudo-isometric form	---	anisotropic to pseudo isotropic	weak	n _e 1.508 n _o 1.509	2.47 (Winchell and Winchell, 1951)
Quartz		variable	weak	----	twinning	---	anisotropic	weak	n _e 1.553 n _o 1.544	2.65 (Winchell and Winchell, 1951)
Australite		brown-green	?	curved	flow marks	transparent	anisotropic	none	1.509	2.4 (Barnes, 1939)

TABLE IV.- CHEMICAL COMPOSITION OF SPHERULES (IN WEIGHT PERCENT)

Spherule	Diameter (microns)	Fluores- cence	Fe	Mn	Ti	Si	Al	K	Ca	Others
<u>METALLIC</u>										
8D14	22	orange	65-70	1-2						
8D19	40	orange	75-80	1-2	<0.5	<0.5				
8D20	20	none	70-75			<0.5				
9D1	25	orange	55-60	<0.5						
9D10	30	orange	55-60	0.5						
9D12	20	orange	50-55	<0.5						
9D14	20	orange	55-60		<0.5					
9D15	50	none	65-70	1						
9D16	30	orange	65-70	0.5						
9D21	25	none	65-70	1		1-2				
<u>GLASSY</u>										
8D18	40	none	<0.5			?				light elements
9D13	30	orange	2-3		1	50-55	10-15	1	1	light elements

Analysis conducted by Advanced Metals Research Corp., Summerville, Massachusetts through the cooperation of Dr. Frances W. Wright, Smithsonian Astrophysical Observatory.

TABLE V.- COMPARISON OF DATA FOR METALLIC SPHERULES, ANTARCTIC PENINSULA TRAVERSE

ITEM	Station										
	224	320	464	496	572	636	700	764	840	940	1008
Mean annual snow accumulation (cm water equivalent)	52	42	27	27	20	34	46	33	28	20	35
Mean diameter (microns)	32	32	37	44	51	46	37	39	37	41	40
Frequency (spherules cm ⁻² yr ⁻¹)	0.30	0.22	0.15	0.08	0.14	0.11	0.21	0.11	0.08	0.05	0.09
Annual accumulation (×10 ⁵ metric tons Earth ⁻¹ yr ⁻¹)	1.6	1.2	1.1	1.2	2.4	1.8	1.5	0.9	0.6	0.4	0.8
Station elevation (meters)	1055	857	715	1041	1443	1434	1045	2120	1721	777	520
Surface winds	SE	SE	NE	NE	NE	NE	N	N	E	E	E

FIGURE CAPTIONS

Figure 1.- Route of the Antarctic Peninsula Traverse showing locations of snow core samples for particulate study. (After Behrendt, 1963).

Figure 2.- Contours of surface elevation (light lines) and snow accumulation (heavy lines), Antarctic Peninsula Traverse. (After Behrendt, 1963).

Figure 3.- Mean diameter of metallic spherules as related to snow accumulation.

Figure 4.- Frequency of metallic spherule occurrence as related to snow accumulation.

Figure 5.- Relation of annual deposit of metallic spherules to snow accumulation.

Plate I.- Metallic Particles of Several Types. Magnification 200X

1. Left, metallic spherule with mottled surface, station 572. Diameter 50μ .
Right, spindle-shaped metallic particle, same station. Diameter 40μ .
2. Smooth, polished metallic spherule, station 496. Diameter 30μ .
3. Smooth, polished metallic spherule, station 764. Diameter 40μ .
Note cupule (arrow).
4. Smooth metallic spherule, station 224. Diameter 30μ . Note cupule (arrow).
5. Pitted metallic spherule, station 1008. Diameter 30μ . Note cupule (arrow).
6. Mammillary particle, consisting of 60μ and 40μ pitted metallic spherules, station 840.
7. Smooth metallic spherule, station 700. Diameter 40μ .
8. Left, metallic spherule with ridged and furrowed surface, station 572. Diameter 30μ . Note cupule (arrow). Right, cindery metallic particle with irregular surface, station 572. Diameter 70μ .

Plate II.- Glassy Spherules. Magnification 200X

1. Light yellow glassy particle, station 940. Diameter 170 μ (100X).
2. Yellow spherule, station 636. Diameter 150 μ (100X). Note internal strain feature (arrow).
3. Yellow-orange spherule, station 940. Diameter 60 μ . Note fractured portion (arrow).
4. Yellow hemisphere, station 700. Diameter 70 μ . Note 5 μ -thick walls (arrows).
5. Smoky gray spherule, station 224. Diameter 100 μ (100X).
6. Smoky gray spherule, station 764. Diameter 100 μ .
7. Clear spherule, station 464. Diameter 60 μ .
8. Light yellow spherule, station 572. Diameter 70 μ .

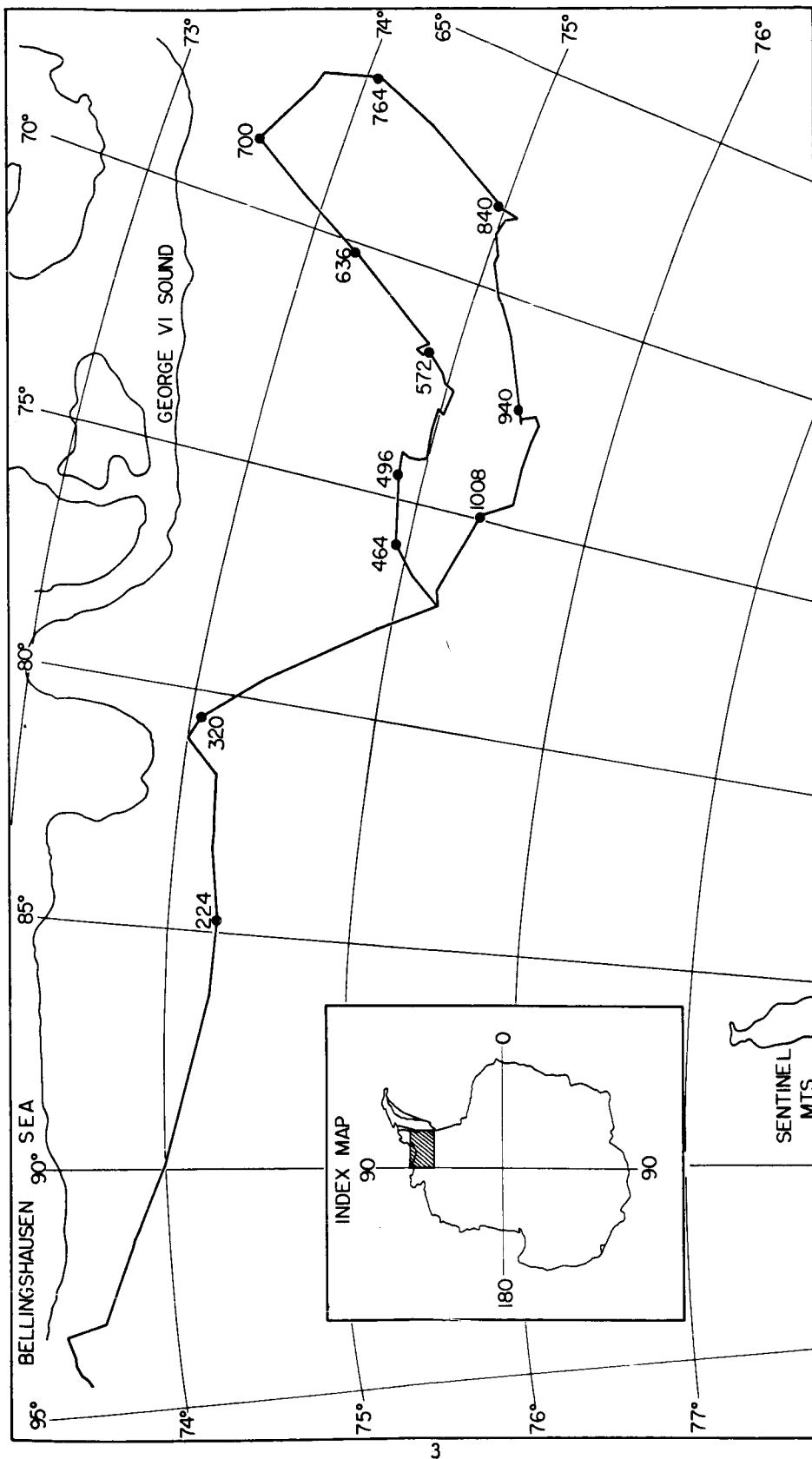


Figure 1

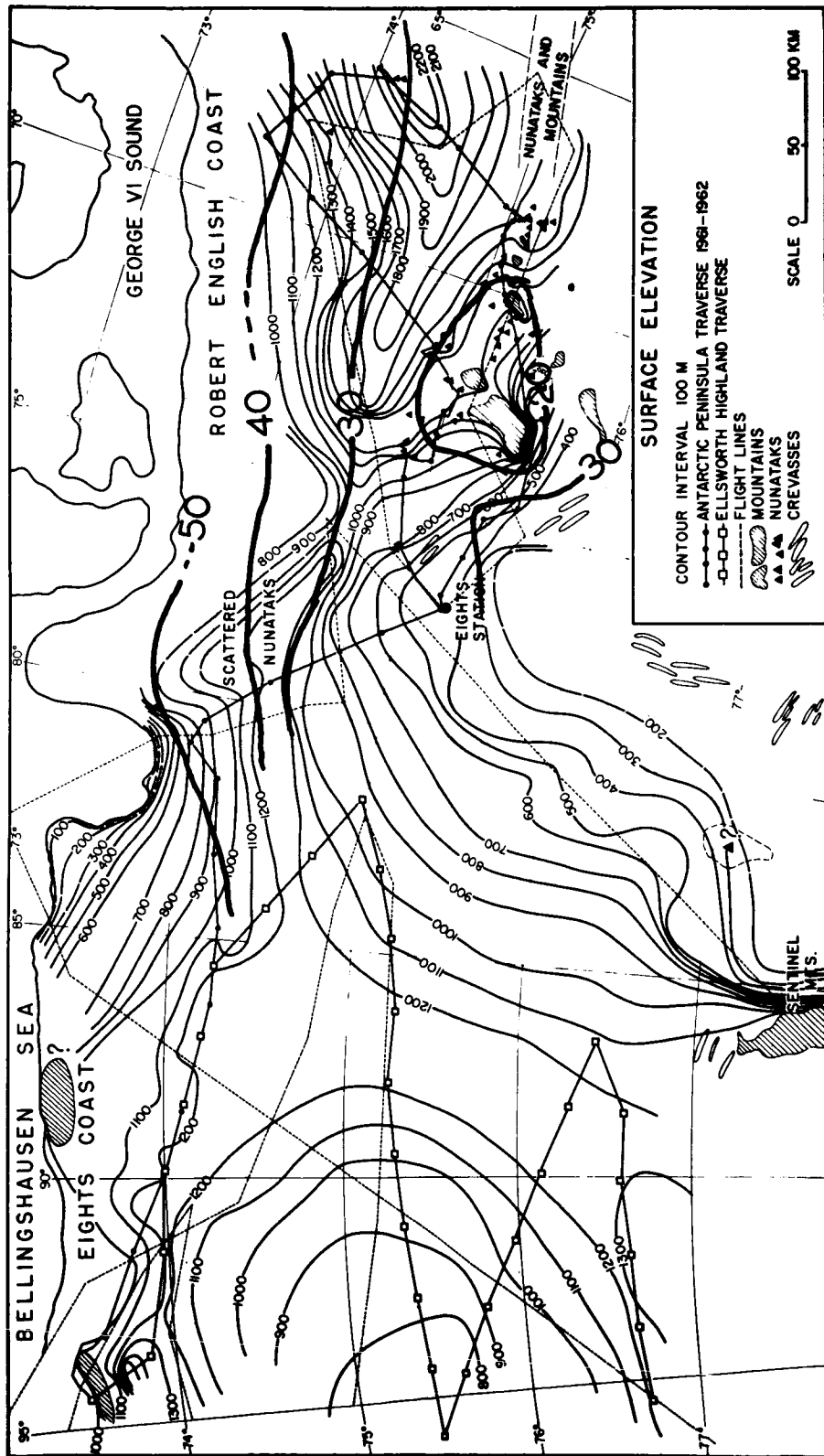


Figure 2

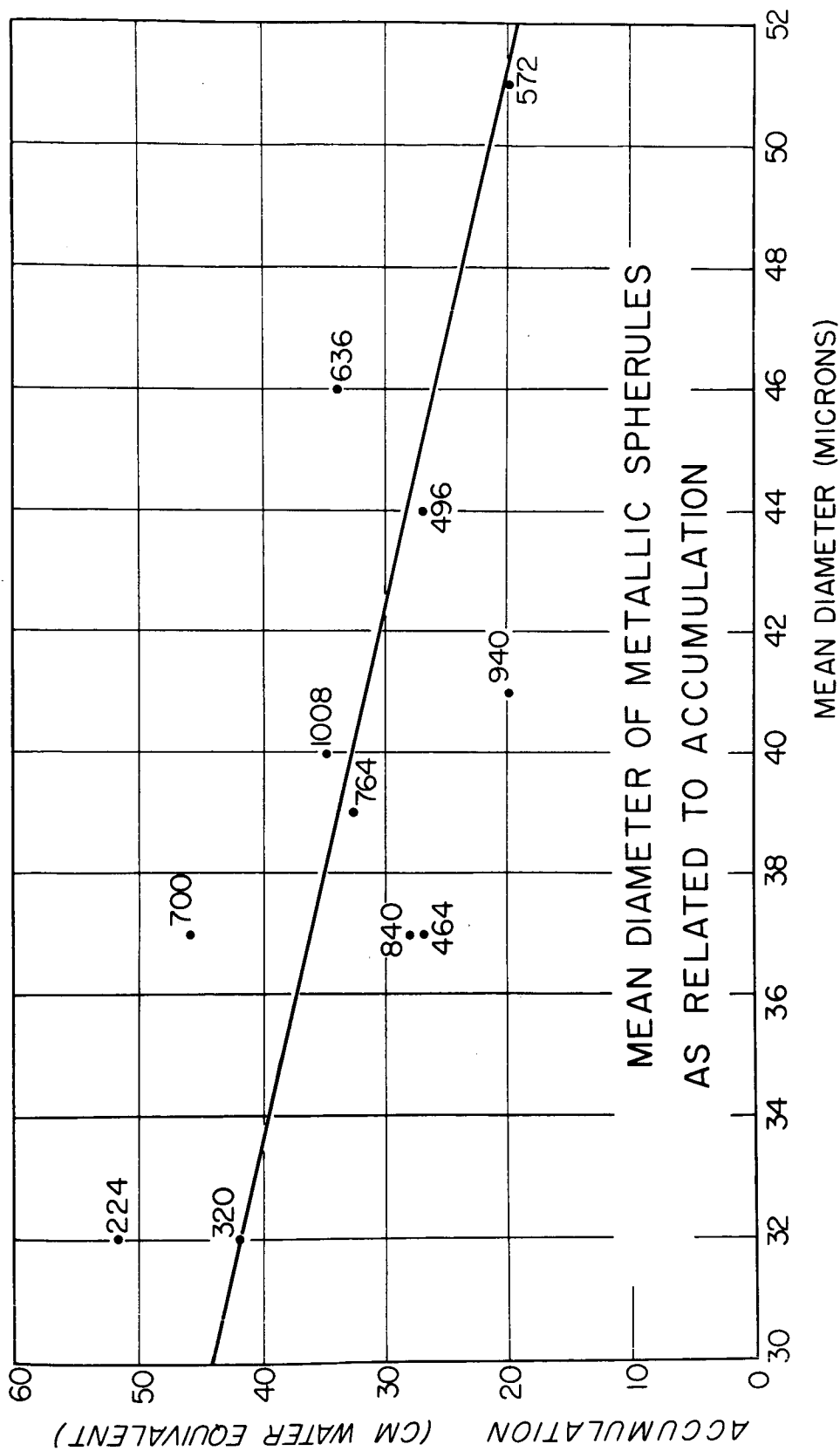


Figure 3

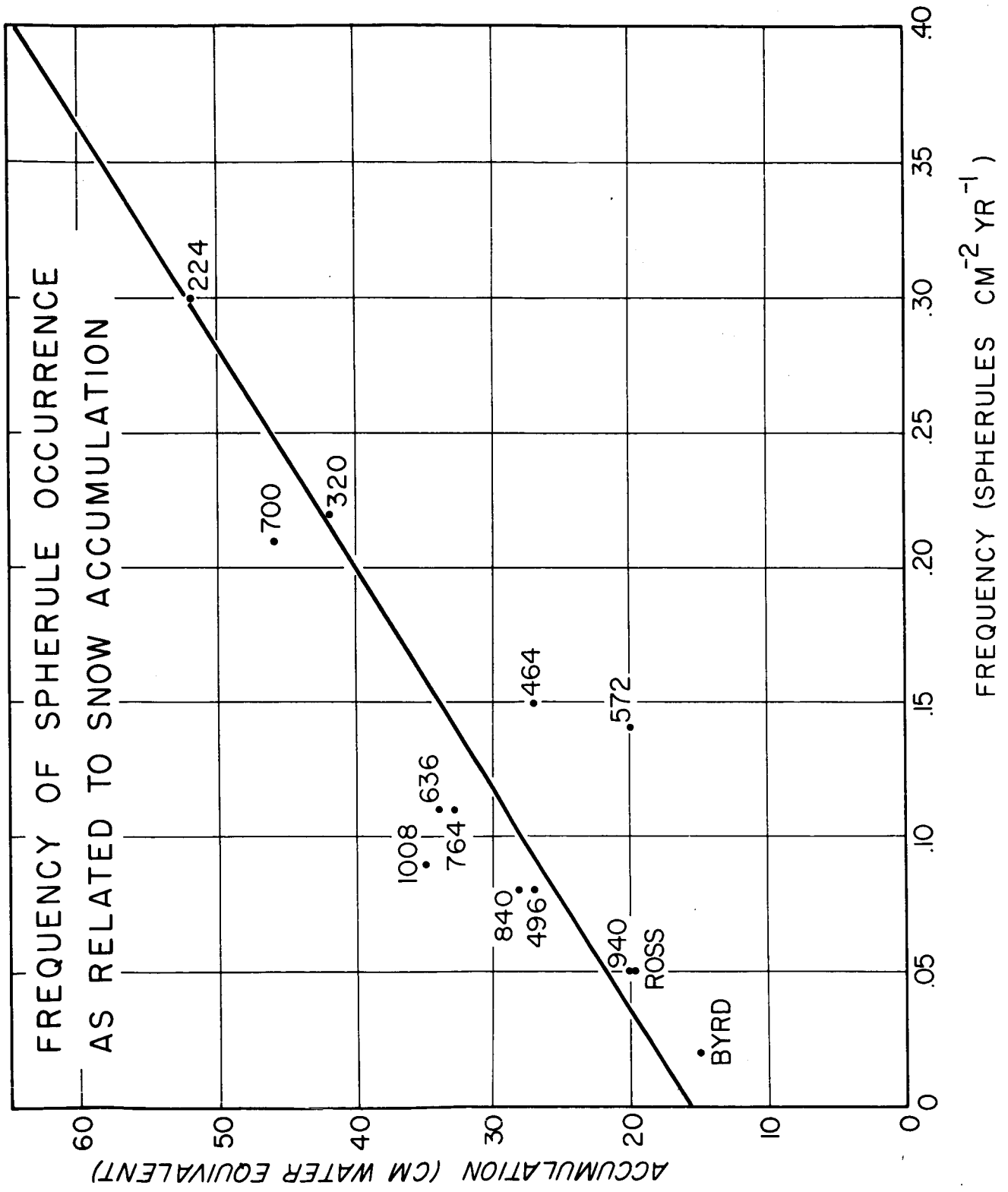


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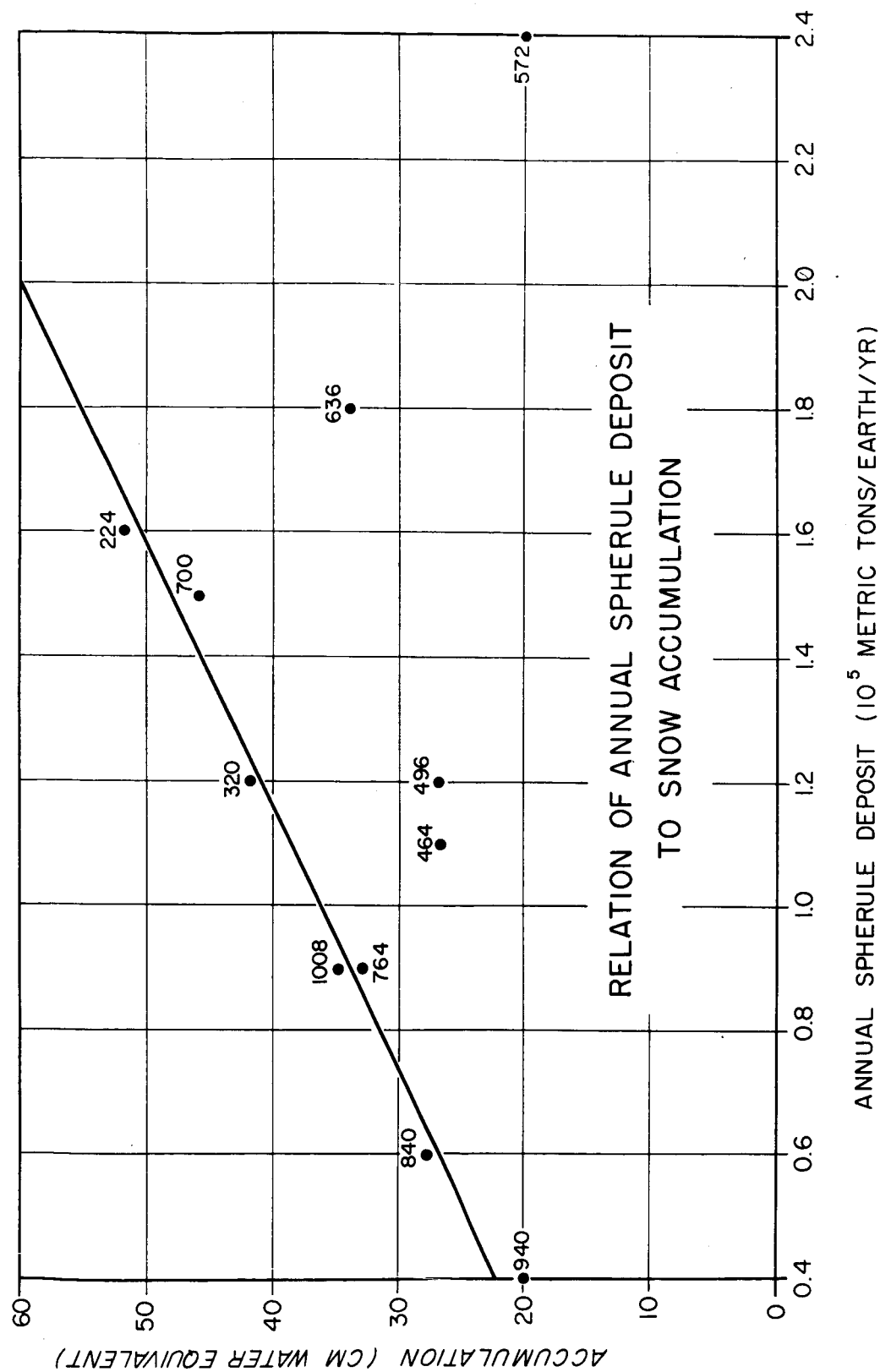


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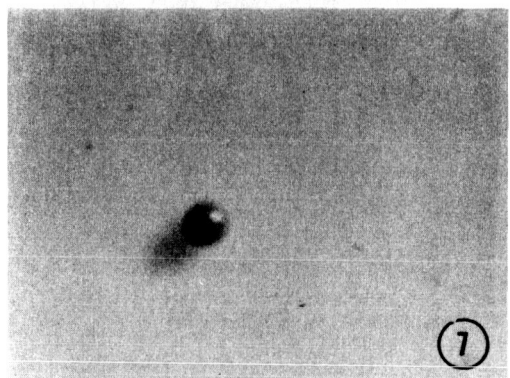
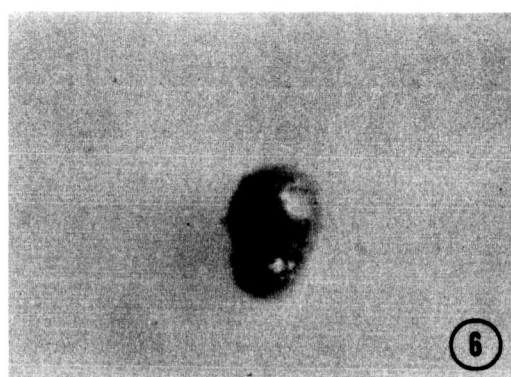
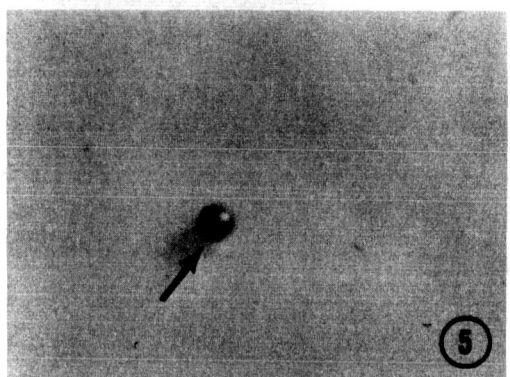
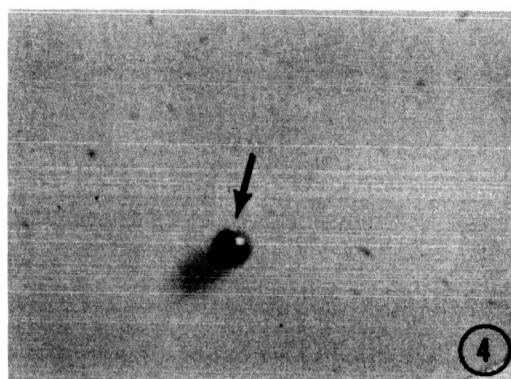
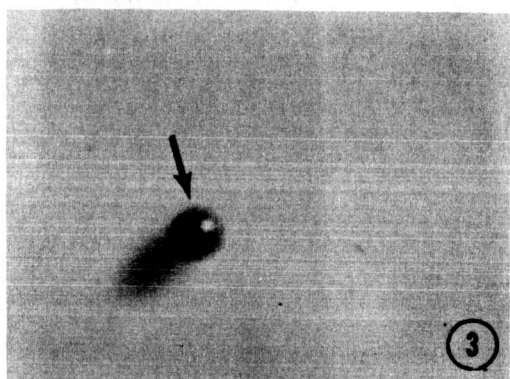
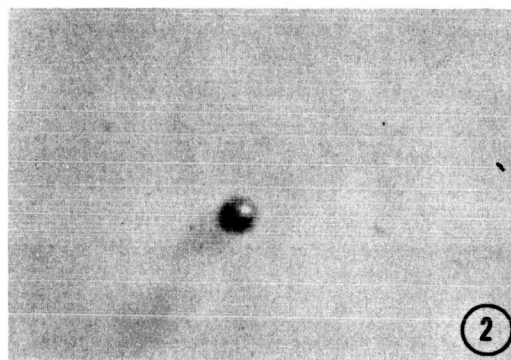
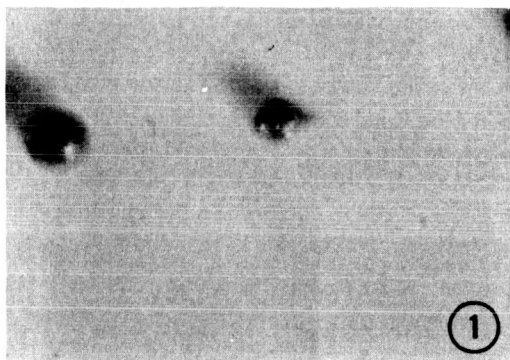


Plate 1

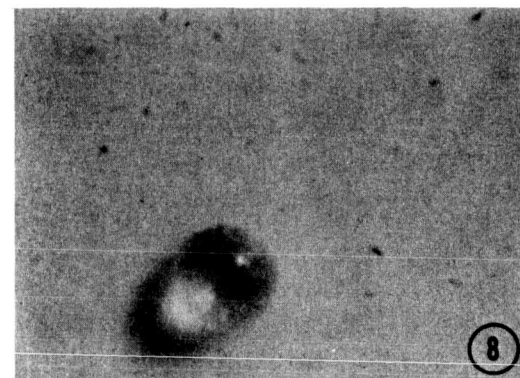
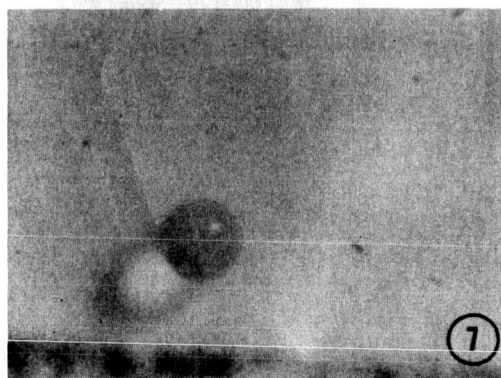
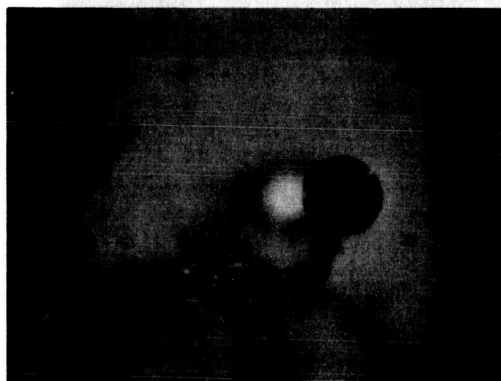
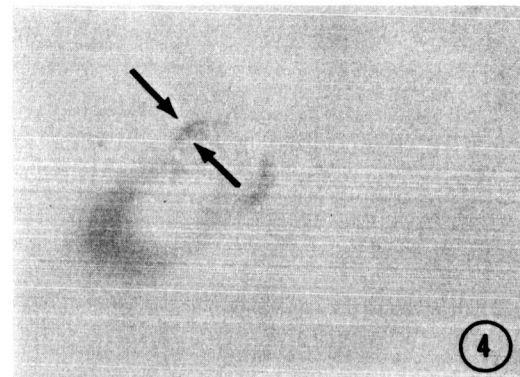
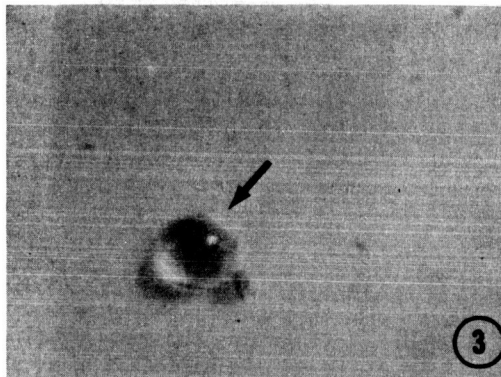
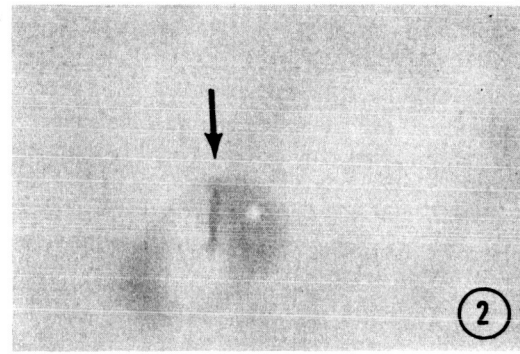
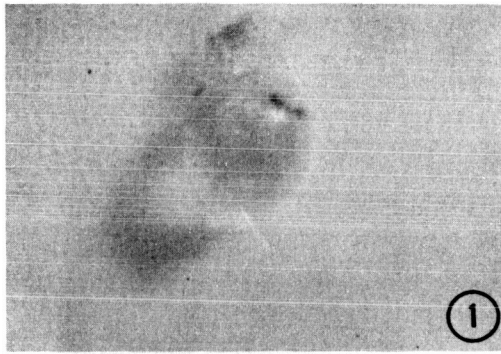


Plate 2